National Naofabrication Users Network

Research Experience for Undergraduates

1998 Convocation

UNIVERSITY OF CALIFORNIA, SANTA BARBARA

National Nanofabrication Users Network

Thursday August 13th - All events are at Engineering II Pavilion

Welcome to Santa Barbara, *and to the 1998 NNUN REU Convocation. Somehow, another summer has flown by, and it seemed that it was just last week that the program had started, and interns and mentors were just meeting for the first time. Yet here we are, at the program's end and, with two fully-packed days of your presentations, which range over an impressively diverse set of topics. Your talks cover the full gamut of research beginning with basic characterization of novel materials, development of patterning and fabrication processes to use on those materials, and culminating in the formation of a variety of mechanical, electronic and biological devices. I hope that you will all enjoy and take advantage of the next few days of learning, sharing experiences, and (if the weather cooperates), enjoying the Santa Barbara sunshine and blue skies.*

Dr. Evelyn Hu, Director,
Center for Quantized Electronic Structures
(QUEST)

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The National Nanofabrication Users Network Research Experience for Undergraduates Program is generously supported by the National Science Foundation, the NNUN Sites, and Industry Sponsors.

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On Thursday August 13th, participants will be arriving at Santa Barbara. Accommodations have been arranged for the NNUN REU interns at the Motel-6 in Goleta. Transportation from the Airport to the Motel will be provided.

6:00 - 8:00 ORIENTATION / PIZZA (ENGINEERING II PAVILION)

Friday August 14th - All events are at Engineering II Pavilion

7:30 - 8:00 REGISTRATION AND CONTINENTAL BREAKFAST

8:00 - 8:15 CHANCELLOR'S WELCOME

8:15 - 8:40 GUEST PRESENTATION: PROFESSOR UMESH MISHRA, UCSB

Understanding The Building Blocks: Materials Synthesis And Characterization

Techniques for Characterization and Growth:

8:41 - 8:53	Gavin Scott	UCSB	Near-Field Scanning Optical Microscopy and Fiber Optic Tips
8:54 - 9:06	Ali Herrera	UCSB	Near Field/ Atomic Force Microscopy Using GaN Lenses
9:07 - 9:19	Philip Jones	CNF	Fabrication of Arrays of Step-Free Areas on Si(111)
9:20 - 9:32	Ben Sturm	CNF	Characterization of Thin Films Deposited using Highly Collimated Molecular Beams of Variable Kinetic Energy
9:33 - 9:45	Patricia Valenzuela	UCSB	Mechanical and Microstructural Properties of Lightweight Ceramic Ablators

9:46 - 10:00 BREAK

Silicon and Oxide-based Materials:

10:01 - 10:13	Jackson Lee	PSU	An Approach to Electron-Beam Induced Non-Epitaxial Crystallization of Amorphous Si Thin Films
10:14 - 10:26	Isaiah Williams	PSU	Film Thickness' and Surface Topology Measurements Support the Successful Growing of Ferroelectric $SrBi_2Ta_2O_9$ Thin Films
10:27 - 10:39	Phyllis Chen	SNF	Grain Structure in Thin Polycrystalline Lines
10:40 - 10:52	Kyndall Barry	SNF	Studying Electronic Transport and Band Structure of New Silicon-Based Heterostructures Involving Alloys of C in SiGe

III-V Heterostructures and Nanostructures:

10:53 - 11:05	Catherine McPherson	HU	Characterization of Polyethylene Wear Particles from Artificial Implants using Atomic Force Microscopy
11:06 - 11:18	Thomas Davidsmeier	CNF	Fabrication of Photonic Bandgap Crystals
11:19 - 11:30	Andrew MacBeth	SNF	Control of AFM Anodization for Lithography of Single-Electron Devices
11:31 - 11:43	Katie Wooten	UCSB	II-VI Semiconductor Nanocrystals Synthesized in Solution Phase

11:44 - 12:35 LUNCH (PHOTO SESSION WILL RUN SIMULTANEOUSLY)

Photo Session Lineup: (1) HU; (2) PSU; (3) CNF; (4) SNF; (5) UCSB; (6) ALL

12:40 - 1:00 GUEST PRESENTATION: DR. VIRGIL ELINGS, PRESIDENT & COFOUNDER, DIGITAL INSTRUMENTS, INC

Putting It All Together: Planar Devices

1:01 - 1:13	Jeremiah Smith	HU	A Novel Nanofabricated Selective Black Body Emitter
1:14 - 1:26	Chancy K. Schulte	SNF	The Enabling of Germanium Processing and Measurement of RF Magnetron Sputtered Film Uniformity for Dark Matter Detectors
1:27 - 1:39	Michael Gutman	CNF	Fabrication and Characterization of Silicon Carbide MOS Capacitors
1:40 - 1:52	Ashish Ahuja	SNF	Fabrication of Sub-Micron Spin-Dependent Tunneling Junctions using E-Beam Lithography
1:53 - 2:05	Tanja Cuk	SNF	Fabrication of Nanostressors for Patterned Self-Assembly of SET Junctions

2:06 - 2:30 BREAK

Microelectromechanical Structures (MEMS)

2:31 - 2:43	Sigal Bekker	CNF	Optimization of Dry Plasma Etching
2:44 - 2:56	John Jochum	CNF	SCREAM Applications: Flow Visualization with Microfluidic Channels
2:57 – 3:09	Sarah Carroll	CNF	Fabrication of Composite Cantilever Beams for Microelectromechanical Systems (MEMS)
3:10 - 3:22	Erick Lavoie	CNF	Fabrication of Composite Cantilever Beams for Microelectromechanical Systems (MEMS)

3:23 – 4:20 GROUP SESSIONS

4:21 - 7:30 BBQ (Goleta Beach)

Saturday August 15th - All events are at Engineering II Pavilion

7:30 - 8:00 CONTINENTAL BREAKFAST

8:01 - 8:15 INTRODUCTION TO DAY 2

8:16 - 8:40 GUEST PRESENTATION: DR. ANGELA BELCHER, UCSB

Nanofab In The Biological Realm

8:41 - 8:53	Marc Meyer	CNF	Patterned Planar Electrode Arrays for Measuring Neuronal Circuits
8:54 - 9:06	Diana Landwehr	CNF	Electrical Array for Electrode Studies of Aligned Nerve Cells in Culture
9:07 - 9:19	Helena Holokova	UCSB	Phage Display Libraries used for Inorganic Material Recognition
9:20 - 9:32	Rafael McDonald	UCSB	Surface Organization by Non-Lithographic Techniques
9:33 - 9:45	Yuri Dancik	SNF	Protein Crystal Growth on Rough Silicon Surfaces
9:46 - 9:58	Blair Irwin	SNF	Microstamping Mazes onto Glass Substrates in Order to Isolate Integral Membrane Proteins Through Microelectrophoresis

9:59 - 10:15 BREAK

10:16 - 10:28	Linda Steinberger	UCSB	The Effects of Adding Emulsions to a Polyacrylamide Gel
10:29 - 10:41	Raiza Calderon	HU	Designing an Internal Dialysis Unit (1)
10:42 - 10:54	Tavia Marshall	HU	Designing an Internal Dialysis Unit (2)
10:55 - 11:07	LaRon Phillips	HU	Designing an Internal Dialysis Unit (3)

Forming The Patterns: Lithography And Other Approaches

11:08 - 11:20	Joe Altepeter	SNF	Inducing Protein Crystallization Using the Electric Field from an Atomic Force Microscope
11:21 - 11:33	Eric Hayduk	CNF	Characterization of "Next Generation" Supercritical CO_2 Developable Photoresists for Use in the Synthesis of Non-Wetting Surfaces and Other Lithographic Applications
11:34 - 11:46	Glenn Deardorff	PSU	UV - Ozone Development Steps for Contrast Enhancement in Electron Beam Lithography Using Ultrahigh Resolution Monolayer Resists
11:47 - 11:59	Corina-Elena Tanasa	SNF	Resist Charging and Heating in E-Beam Lithography

NOON – 12:59 LUNCH

Transferring The Pattern: All Kinds Of Etching

1:00 - 1:12	Keith Slinker	CNF l	Fabrication of High Aspect-Ratio Nanometer-Scale Structures using Electron Beam Lithography and Reactive Ion Etching
1:13 - 1:25	Jeremy Rowlette	PSU	High-Resolution Dry Etching of Si-Based Dielectrics Using a Chemically Amplified Electron Beam Resist
1:26 - 1:38	Mahima Santhanam	PSU	Etching in $Si0_2$ in High Aspect Ratio Trenches
1:39 - 1:51	Lezlie Potter	UCSB	Laser Enhanced Debonding of Nitride Semiconductor Films
1:52 - 2:04	Samual Bishop	SNF	Process Development of Chlorobenzene and LOL2000 Liftoff Processes with Stable Overhang Structures
2:05 - 2:17	Nin Loh	SNF	Characterization of Plasma Etching Using Alternative Gases
2:18 - 2:30	Benjamin Werner	UCSB	Annealing Behavior of Ar^+ Plasma-Damaged InAs Quantum Dots and InGaAs Quantum Wells

2:31 – 3:30 GROUP SESSIONS

3:31 – 3:59 WRAP UP

4:00 - 7:30 BBQ (CLIFF HOUSE AT SANDS BEACH)

THE 1998 NNUN REU ABSTRACTS

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In Alphabetical Order
by Intern's Last Name

Fabrication of Sub-Micron Spin-Dependent Tunneling Junctions using E-Beam Lithography

Ashish Ahuja, SNF

Manish Sharma, Electrical Eng, Stanford University
Shan X. Wang, Mat Sc. Eng and Electrical Eng, Stanford University

The Spin Dependent Tunneling (SDT) effect provides a way of making non-volatile magnetic memory. In an SDT device, the mode of electron transport is by quantum-mechanical tunneling across a thin dielectric barrier. Due to a ferromagnet-dielectric-ferromagnet architecture, the tunneling current is polarized in spin, and consequently magnetoresistive effects are observed.

The focus of the project is to fabricate submicron SDT's so that we can (a) study their switching properties and (b) observe the area-dependence of the MR effect to explore the possibility of memories with high-densities. A bilayer photoresist process compatible with e-beam patterning was developed in the first part of this project. The junction features desired essentially require the presence of sufficient undercut in the bottom resist layer. We have used PMGI and SNR200 deep-UV photoresists to achieve this bilayered structure. Resist features as small as 0.2 micron in size and with a sufficient undercut have been achieved. Currently, actual SDT junctions are being fabricated using this process.

Inducing Protein Crystallization Using the Electric Field from an Atomic Force Microscope

Joe Altepeter, SNF

Peter Griffin, Stanford University

X-ray diffraction can determine the structure of protein molecules given a protein crystal. A protein crystal consists of an ordered array of identical molecules which bond together due to intermolecular attractions. While crystallization of most proteins is trivial when an existing crystal seed is available, the initial crystal sample is often difficult to generate. Because of the highly polar structures of protein molecules, I am attempting to induce crystallization using an electric field. An Atomic Force Microscope (AFM) will both generate this electric field and use tapping mode imaging to monitor the protein crystal's development. An AFM uses force microscopy rather than reflected light or electrons to image a surface. The extremely sharp silicon nitride AFM tip actually moves over the surface to be analyzed, while a deflected laser beam registers the change in height. The AFM also has the capability to generate an electric field through the metal coated lithography tip. To study the electric field generated by the AFM, I have used it to oxidize hydrogen-terminated silicon. By using oxidation lithography first in air and later in water, I will demonstrate the capabilities of this electric field and the limitations of the AFM. Next, I will attempt to crystallize protein samples in solution using this field.

Studying Electronic Transport and Band Structure of New Silicon-Based Heterostructures Involving Alloys of C in SiGe

Kyndall Barry, SNF

James Gibbons, Stanford University
Judy Hoyt, Stanford University

Si-based heterostructures involving alloys of C in Si and SiGe expand the range of device applications for Si-based heterostructures. Adding carbon to the compressed SiGe lattice relaxes the strain and allows for the growth of thicker layers. This provides greater flexibility for device designs. Previous work at Stanford has shown that high quality SiGeC with up to 2 at. % substitutional carbon can be grown.

In this study, SiGeC wafers grown by two different methods, Molecular Beam Epitaxy (MBE) and Chemical Vapor Deposition (CVD), were processed into n-type MOS capacitors. The resulting capacitors where used to compare conduction band offsets for CVD and MBE grown epitaxial layers. In recent experiments, conduction band offsets were reported for MBE grown material, but were not reported in separate CVD grown Si/SiGeC.

By comparing measured and simulated MOS capacitance vs. voltage (C-V) measurements, conduction band offsets can be extracted. In SiGe, conduction band offsets are expected to depend on carbon percentage.

MBE grown material exhibited well-behaved MOS-CV characteristics for C concentrations up to ~1.2 at. % with no evidence of conduction band offsets. However, for C concentrations of 1.4 and 1.9 at. %, traps, non-ideal behavior, and excessive freeze out at low temperatures were observed in the MBE material. Further measurements and analysis are underway. These preliminary findings are in agreement with results seen in CVD tests at Stanford, and it can be concluded that the conduction band offsets of both CVD and MBE materials are small.

Optimization of Dry Plasma Etching

Sigal Bekker, CNF

Hercules Neves, Electrical Engr, Cornell University

As dimensions of integrated circuits are being minimized, efforts are being made to reduce roughness of device sidewalls. Dry plasma etching of silicon is the main step in achieving uniformity and smoothness of features. The predominant method for dry plasma etching has chlorine as its main component. This technique allows for fine features (<1 um) to be etched leaving smoother sidewalls behind. Although it has been providing two decades of efficient device processing, chlorine etching indeed has some side effects. Aside from slightly tapered sidewalls, its potential for trenching, and poor selectivity to oxide mask, the C_{l2} technique has a low etch rate. This provides a serious obstacle and demand for new techniques has been on the rise. The Bosch method of dry plasma etching revolutionized micromachining architecture about 1.5 years ago. Indeed this new technique offers a fast etch rate, high selectivity and very vertical sidewalls. Both oxide and photoresist masks can be used. Many parameters can be manipulated during Bosch etches in order to fine-tune the final product. So many parameters, in fact, that the task of constructing a recipe for a specific etch is not trivial. The Bosch process brings along some flaws as well. Mask undercutting and ripples on the sidewalls are observed. Fine features or shallow etches are almost impossible to fabricate. This new technology is yet to be fully explored. The focus of this research is in finding a midpoint, a balance between chlorine and Bosch etching, that will maximize the advantages and minimize the disadvantages. If achieved, this can have a great impact on the optics and electromechanical microfabrication industry.

Process Development of Chlorobenzene and LOL2000 Liftoff Processes with Stable Overhang Structures

Sam Bishop, SNF

James Harris, Electrical Engr Dept, Stanford University

In a lithographic lift-off process, a resist pattern is formed prior to evaporating metal for wiring. The metal on top of the resist pattern is lifted off with the photoresist in an acetone strip. Previous techniques subtractively etched off metal before stripping the resist. A lift-off process eliminates the metal etching step. The key feature of a lift-off process is an undercut resist profile. However, resist patterns from positive photoresist alone do not result in undercut profiles.

Two processes were developed to induce undercutting in the resist. The first process involved soaking photoresist covered wafers in chlorobenzene either before or after exposure. The chlorobenzene diffuses into the resist and lowers the development rate of the top portion of the resist layer. The second process places the resist layer on top of a layer of the chemical LOL2000. LOL2000 is not photosensitive and has a faster development rate than the resist. In both processes, the difference in development rates leads to an undercut profile.

For the chlorobenzene process, the variables to optimize were, resist baking time, chlorobenzene soaking time, exposure time and development time. Chlorobenzene soaking and development times were kept constant for all samples. An optical microscope was used to measure sample exposure level. A scanning electron microscope was used to analyze the resist profiles. Overhang and height values were quantified using the SEM. Appropriate undercut profiles were achieved for chlorobenzene soaking before and after exposure using Shipley 1813 photoresist. Results for the LOL2000 process are pending.

Designing an Internal Dialysis Unit

Raiza Calderon, HU

Kimberly L. Jones, MSRCE, Howard University

The objective of this research was to design an efficient, yet biocompatible dialysis unit for internal use. The design of the model was to incorporate the functions and components of traditional dialyzers into a miniaturized unit, with a focus on membrane fabrication. Initially, it was intended to fabricate the membrane material in the Howard University Materials Science Research Center of Excellence. However, our research revealed that the optimum material and membrane could not be fabricated in the MSRCE laboratory. Therefore a theoretical model of an internal unit was designed; however, the actual performance of this unit requires physical experimentation. The model of the unit is similar to a square, three-dimensional box with a housed polysulfone membrane sandwiched in between. The effective separation of substances that pass through the membrane is based on the concepts of diffusion by means of countercurrent flow. Micropumps housed in the unit will be used to regulate blood and dialysate flow. Four portals: blood in, blood out, dialysate in, and waste out, provide for the fluid flow throughout the unit. The unit will be attached to the femur, from which blood will enter and exit via the femoral artery and vein. The waste outlet leads to the bladder, where waste is excreted. Dialysate is pumped into the unit using a “strapped beeper unit,” a unit derived from the insulin pump concept.

Fabrication of Composite Cantilever Beams for Microelectromechanical Systems (MEMS)

Sarah Carroll, CNF

Norman Tien, Electrical Engr, Cornell University

Composite structures have applications in MEMS to control ringing in rigid structures. The focus of this paper is the development of a process to create and test composite cantilever beams for microelectromechanical systems (MEMS). These beams were fabricated using polyimide as an interstitial layer between aluminum to act as a dampening material. Furthermore, cantilever beams were chosen to facilitate the measurement of the material properties of the composite.

To fabricate these structures we exploited integrated-circuit fabrication techniques on a silicon wafer substrate. As a result, the fabrication techniques used in this paper can be easily implemented in existing microelectromechanical applications. During the course of this research we had to be particularly attentive to the compatibility of the subprocesses involved in using certain combinations of materials, in addition to maintaining an awareness of material compatibility.

Grain Structure in Thin Polycrystalline Lines

Phyllis Chen, SNF

Jim Plummer, Electrical Engr, Stanford University
Joseph Tringe, Electrical Engr, Stanford University

In today's trend toward smaller, faster microelectronics, there is a strong push to understand the constituent material properties at a micron scale. The structure of polycrystalline silicon grain boundaries influences the electrical properties of the material at this length scale. It is our goal to identify a correlation between the crystallographic orientation of neighboring grains and consequent electrical properties. We measure the resistance of lines approximately the width of a single grain, then physically characterize the structure of the grain boundaries with a transmission electron microscope (TEM). The TEM can image crystal lattices of individual grains, and electrons diffracted by these lattices give distinct patterns that correspond to specific crystal orientations. By taking TEM diffraction patterns of adjacent grains, we can resolve the misorientation angle between these two grains. We recreate this angle of misorientation with a computer program and then use this simulation to calculate the atomic density and geometry of the grain boundary. With this information, we can find the correlation between the grain boundary structure and the resulting electrical resistivity.

Fabrication of Nanostressors for Patterned Self-Assembly of SET Junctions

Tanja Cuk, SNF

Cheng-Yu Hung, Stanford University
Richard Kiehl, Stanford University

Single Electron Tunneling Junctions (SETs) are very thin capacitors in which a single electron tunnels across when biased correctly. They are essential components of single electron transistors, a new kind of technology that promises to surpass the density of CMOS in logic operations by three orders of magnitude.

One way of fabricating these junctions is by growing (Molecular Beam Epitaxy) AlGaAs/GaAs quantum wells at low temperature with an excess of 1% Arsenic. Upon annealing, the excess Arsenic precipitates into nanometer-scale spheres that position themselves along the direction of growth in the GaAs layer. In order to position them laterally, InGaAs stressors are placed on the surface. The higher lattice constant of InGaAs causes higher energy areas underneath, relaxed by the formation of Arsenic precipitates.

So far, the stressors have been placed in lateral arrays, successfully positioning the precipitates in lines. I will attempt to position the precipitates in the x and y direction by fabricating arrays of square stressors. I hope to locate only one precipitate under each stressor. I will use Electron Beam Lithography to map the arrays and the Scanning Electron Microscope to view the precipitates.

With the precise location of Arsenic precipitates, uniform capacitors can be made (arsenic being the metal “plates” and GaAs being the dielectric). The dimensions of the capacitors would be perfect for use as SET junctions. They are thin enough so that electrons can tunnel across and yet small enough in area so that the capacitance is below one atto Farad.

Protein Crystal Growth on Rough Silicon Surfaces

Yuri H. Dancik, SNF

Jim Plummer, CIS, Stanford University
Peter Griffin, CIS, Stanford University

Protein crystals are often used to determine the atomic structure of a protein molecule through X-ray diffraction. However, growing protein crystals requires a large amount of trial and error. For some proteins, crystals will not grow under any conditions. The goal of my project is to induce protein crystallization by using ledges, steps, and terraces as an initial crystal site. Crystals form by protein molecules attaching to terraces and ledges. The molecules diffuse from the protein solution onto the terraces, and further to the ledges and kinks.

The first step in the formation of crystals is nucleation, in which at a high enough solute concentration, a nucleation energy barrier is overcome and some molecules in the protein solution come together to form a stable aggregate. The aggregate forms a repeating lattice with a well defined structure. If the initial nucleus does not form, crystals will not grow.

I will attempt to induce protein crystallization by depositing a sample of protein solution on pieces of roughened Si wafers. Less energy is required to make molecules bind to a rougher surface than to a smoother one. I hope to decrease the nucleation barrier and increase the likelyhood that several protein molecules will aggregate together, forming the initial crystal nucleus. I have been etching Si wafers in KOH solution of varying concentrations and for different times. The roughness of the wafers can be observed on an atomic scale using an Atomic Force Microscope (AFM). So far I have observed random pits, edges and terraces with depths in the order of 40-60 ≈ on wafers etched in 25% and 45% KOH solution. Deformations of the order of 100-150 ≈ would be more desirable, since this is the typical size of protein molecules. I will soon use these roughened wafer surfaces to try to make protein crystals grow.

Fabrication of Photonic Bandgap Crystals
Thomas Davidsmeier, CNF

Yuri Suzuki, Cornell University

If two media have sufficiently different dielectric constants, certain arrangements may exhibit photonic bandgaps. The underlying physics of these photonic crystals and the theoretical considerations necessary to determine what arrangements will possess bandgaps is discussed. From low pass filters to optical circuit elements, photonic crystals present many fascinating possible uses. To reach their full potential, photonic crystals must be made with the proper bandgaps. We fabricated a photonic crystal on a single crystal silicon wafer. We also attempted to couple the crystal to optical fibers via devices on the same wafer. Optical spectra for our assemblies will be presented.

UV - Ozone Development Steps for Contrast Enhancement in Electron Beam Lithography Using Ultrahigh Resolution Monolayer Resists
Glenn Deardorff, PSU

David L. Allara, Dept of Chemistry, Pennsylvania State University

Previous work, in collaboration with Harold Craighead (Cornell NNUN facility), has shown that a UV-ozone development step can improve etch contrast in e-beam patterning of Si using self-assembled monolayer (SAM) resists. In the present study, real time infrared spectroscopy measurements will be applied to characterizing the chemical changes occurring during UVO treatment of octadecylsiloxane (ODS) SAMs on Si wafers before and after e-beam doses typical for lithography. An infrared spectrometer outside of the main fabrication facility has been set up with a dual lamp UV source enclosed in an inner sample chamber isolated by IR transparent windows. Signal to noise ratio tests have shown that changes in the film chemical structures on the submonolayer scale can be followed. High quality ODS films have been prepared in a controlled humidity chamber. Experiments are now underway in which the scanning electron microscope located in the nanofabrication facility is being used to irradiate ~1 cm^2 regions of the samples which then will be subjected to UVO treatment in the IR chamber.

Fabrication and Characterization of Silicon Carbide MOS Capacitors

Michael Gutman, CNF

Kevin T. Kornegay, Electrical Engr, Cornell University

The interest in using Silicon Carbide (SiC) as a semiconducting material has increased in recent years due to its potential in microelectronic applications that involve high power, high temperature, and high frequency. Because of this, experimentation on Metal Oxide Semiconductor (MOS) devices which utilize SiC as the semiconductor is essential to develop further understanding of Silicon Carbide's potential. One of the devices used for this study is the MOS capacitor. Numerous SiC capacitors are fabricated and characterized to determine their current-voltage characteristics. The fabrication procedure involved numerous stages including oxidation, metal deposition, and photolithography. In doing the fabrication, we were able to standardize a method for future SiC device fabrication as well. The fabrication process along with the analysis results will be described in this talk.

Characterization of "Next Generation" Supercritical CO_2 Developable Photoresists for Use in the Synthesis of Non-Wetting Surfaces and Other Lithographic Applications

Eric J. Hayduk, CNF

Narayan Sundararajan, MSE, Cornell University
Christopher K. Ober, MSE, Cornell University

As the microelectronics industry grows, it constantly demands improvements in photolithographic techniques that lead to smaller integrated circuits and other electronic components. To that end, fluorinated block copolymer photoresists have been developed for exposure at 193 nm. These resists promise both high resolution and selective solubility in supercritical carbon dioxide (SC CO_2). SC CO_2 offers a cost effective, environmentally friendly alternative to conventional aqueous solvent systems.

Several photoresist systems that utilize SC CO_2 as a developer were characterized. Parameters including the exposure dosage, minimum resolvable feature size, CF_4 plasma etch rate and optimum temperature; pressure solubility conditions were determined. Results indicate that exposure doses are less than 10 mJ/cm^2 for selected photoresists and features down to 0.3 μm are resolved. Their etch rates varied from 800 to 1300 Å/min and solubility conditions ranged from 2800 psi, 45°C to 7000 psi, 85°C.

Finally, as a novel application of fluorinated block copolymers, high contact angle (150°), non-wetting surfaces which mimic the topography of Lotus leaves were manufactured. Ultimately, the goal is to synthesize surfaces with contact angles greater than 160° for use as innovative coatings. In this case, the surfaces become self-cleaning and easily wash away surface particulate matter.

Near Field/ Atomic Force Microscopy Using GaN Lenses

Ali Herrera, UCSB

D.K. Young, Quantum Institute, UCSB
D.D Awschalom, Quantum Institute, UCSB

Gallium nitride hexagonal pyramids as possible lenses for a near field/ atomic force microscope are described. The main objective of the project was to determine if the pyramids behaved as micron scale lenses focusing light down to 100nm. The advantages of a combined microscope using GaN lenses include increased spatial resolution, simplified piezoelectric feedback system, and simply a more durable user-friendly microscope. 5μm, 8μm, 10μm, pyramids grown on a sapphire substrate are compared in terms of defects and distances between pyramids. GaN pyramids were tested and found to focus light. Two methods were employed: photolithography and scanning near field optical microscopy. A novel design for the microscope cantilever is presented.

Phage Display Libraries used for Inorganic Material Recognition

Helena Holeckova, UCSB

Angela Belcher, David Margolese, Galen Stucky and Evelyn Hu, UCSB

Nature uses unique characteristics, which are desirable for material design and synthesis, including high selectivity, nanoscale self-assembly and precise structure control. Our approach to nanofabrication and patterning inorganic materials, such as metals, magnetic materials and semiconductors, is to use the precise material and structure recognition of biological systems. We are using combinatorial method called phage display libraries to isolate polypeptides that will specifically recognize, bind and nucleate inorganic nanoparticles.

Currently, we are using iron oxide particles: Fe_2O_3, Fe_2O_3 and Fe_3O_4. So far, we have been successful in synthesizing Fe_3O_4 particles. The synthesis of the Fe_2O_3 particles hasn't given us the desired product, so we are working on modifying the procedure. The synthesis of the Fe_2O_3 particles hasn't been done yet. Most of the particles were characterized by IR spectroscopy and x-ray diffraction. Now, we are ready to start attaching polypeptides to the Fe_3O_4 particles.

Microstamping Mazes onto Glass Substrates in order to Isolate Integral Membrane Proteins through Microelectrophoresis

Blair Irwin, SNF

Mary Tang, Dept of Electrical Engr, Stanford University
Curt W. Frank, Dept of Chemical Engr, Stanford University

All living beings are made of cells surrounded by a plasma membrane. The plasma membrane is composed of a double layer of lipids studded with proteins. These membrane proteins perform many tasks including the transportation of wastes and nutrients across the bilayer and cell-cell communication. Methods like centrifugation have been established which enable scientists to isolate and study most membrane proteins, but few methods exist for isolating proteins which span the membrane, or integral membrane proteins. The most widely used method for isolating integral membrane proteins, solubilization by detergents, is unreliable and inefficient and often results in a loss of bioactivity and native structure. Our research involves developing a more efficient method for isolating integral membrane proteins in their native state. Our proposal combines two recent scientific developments: microstamping and polymer-supported lipid bilayers. Microstamping is the production of an elastomeric stamp from a silicon wafer which has a pattern of resist generated from photolithography. Supported lipid bilayers are membranes which have been covalently coupled to or separated from solids by ultrathin polymer cushions. These artificial bilayers maintain the structural and dynamic properties of free bilayers and thus serve as an analytical tool for studying cell membranes and membrane-imbedded proteins. Our plan is to use a microstamp to pattern ink on a substrate and then covalently couple polymer to the ink, making a polymer “maze.” We then plan to lay a bilayer containing integral membrane proteins on top of the maze. By applying an electric field to the maze, we hope to sort and later purify the integral membrane proteins by their size and charge. So far this summer we have succeeded in making a microstamp which contains the desired patterns which will later make up our maze. Our plans for the future are to ink and press the stamp and then lay down the bilayer.

SCREAM Applications: Flow Visualization with Microfluidic Channels

John Jochum, CNF

Hercules Neves, Electrical Engr, Cornell University

Microfluidic channels have emerged as an exciting field with a diverse spectrum of applications. At Cornell University, using the SCREAM microfabrication process, microfluidic channels have been incorporated on the same chip with extremely robust, high-aspect-ratio MEMS. Using this established approach to create fluidic-channel MEMS, this report discusses work done to both create and visualize fluid flow. On-chip pumps were designed but not tested, using micromachined actuators coupled with passive flow geometries. Fluid flow visualization through the channels was successfully accomplished using fluorescing microspheres and optical microscopes.

Fabrication of Arrays of Step-Free Areas on Si (111)

Philip Jones, CNF

Jack Blakely, Materials Science & Engr, Cornell University

We report attempts to fabricate arrays of step-free areas on Si(111). The motivation for this research is the fabrication of better microelectronic devices. As device dimensions become smaller, the need for a step-free surface will be critical. These devices will require a much smoother interface between the Si and SiO_2 layers. The reason is that individual steps or step bunches may significantly affect the local field, channel mobility, and breakdown characteristics of such devices.

Two-dimensional grating patterns of ridges were generated on the surface by e-beam lithography, and plasma etching. The patterned areas were then flashed and annealed in an ultra high vacuum at various temperatures and time intervals. The patterned areas were then characterized by atomic force microscopy.

We succeded in fabricating step-free arrays for patterns with a repeat spacing as long as 25μm. For the patterns with a large repeat spacing, we did not see completely step-free areas; however, we could decrease the step density for these areas.

Electrical Array for Electrode Studies of Aligned Nerve Cells in Culture

Diana Landwehr, CNF

Harold Craighead, Applied and Engr Physics, Cornell University

Due to the size and location of the neural-electrode array, directed cell growth is crucial in the fabrication of a feasible neural interface. Therefore the protein patterning must be precise for the neuron processes to grow to the desired electrode. With the previous method of patterning, micro-contact printing, it was difficult to get desired results. However, using photoactivatible and photocleavable biotin conjugates, we can take advantage of the photolithographic methods used by the semi-conductor industry. The strong affinity of the protein's avidin and biotin for each other make them ideal candidates for specific protein patterning.

Fabrication of Composite Cantilever Beams for Microelectromechanical Systems (MEMS)

Erick Lavoie, CNF

Norman Tien, Electrical Engr, Cornell University

Composite structures have applications in MEMS to control ringing in rigid structures. The focus of this paper is the development of a process to create and test composite cantilever beams for microelectromechanical systems (MEMS). These beams were fabricated using polyimide as an interstitial layer between aluminum to act as a dampening material. Furthermore, cantilever beams were chosen to facilitate the measurement of the material properties of the composite.

To fabricate these structures we exploited integrated-circuit fabrication techniques on a silicon wafer substrate. As a result, the fabrication techniques used in this paper can be easily implemented in existing microelectromechanical applications. During the course of this research we had to be particularly attentive to the compatibility of the subprocesses involved in using certain combinations of materials, in addition to maintaining an awareness of material compatibility.

An Approach to Electron-Beam Induced Non-Epitaxial Crystallization of Amorphous Si Thin Films

Jackson Lee, PSU

Stephen J. Fonash, EMPRL, Pennsylvania State University

An energetic electron beam has been used to stimulate non-epitaxial crystallization of amorphous Si thin films. While most e-beam crystallization experiments have dealt with the solid-phase epitaxial crystallization of amorphous zones created in single crystal Si films, our research focused on studying the direct crystallization of PECVD amorphous Si films on glass, specifically Corning 7059. We used 50 keV electron energy in our experimentation, which is significantly lower than electron energy levels used in most earlier work, and found the a-Si samples had to be de-hydrogenated for successful crystallization. We also used a wider matrix of current densities and dosages than previously reported. By using a Leica EBPG5-HR e-beam writer, we produced an array of 0.5 micron diameter crystallized spots separated by 10 microns. After distinguishing crystallized areas through tests in reflectance and transmission, SEM pictures and profilometer readings proved the topography of the spots to be elevated, possibly due to heating of the glass substrate. Electron-beam induced crystallization of materials is a subject that has received much attention in the last several years due to its application in making selected area crystallized regions. With the crystallized spots produced, there is a potential of creating microsized areas in which electronic devices can be built and of creating seeds to control nucleation in solid-phase crystallization. The latter can be used to make larger grains and grain boundaries smaller, which help in lowering intragrain defect density and providing better stability and higher carrier mobilities.

Characterization of Plasma Etching Using Alternative Gases

Nin C. Loh, SNF

James McVittie, Stanford University
Krishna Saraswat, Stanford University

Chlorofluorocarbon (CFC) gases such as $C_2C_lF_5$ (F-115) are used in wafer processing in combination with an etchant like SF_6 to provide a near-anisotropic dry etch. While inert at sea level, these gases release chlorine atoms which catalyze the dissociation of the stratospheric ozone that shields the Earth from harmful ultraviolet radiation. For this reason these gases have been replaced by toxic gases such as chlorine and hydrogen bromide. It is, however, desirable from safety and simplicity standpoints to find alternative non-toxic gases that will give etch properties comparable or superior to formerly used CFCs and not deplete the ozone. We are characterizing the etching performance of two gases, $C_2HC_lF_4$ (F-124) and CHC_lF_2 (F-22) in combination with SF_6. These gases were chosen by for their chemical similarity to $C_2C_lF_5$ and their hydrogen component which significantly reduces their ability to reach the stratosphere. We are studying how their concentration affects the etch rates for silicon oxide, polycrystalline silicon, and photoresist and the profiles of polysilicon etched lines. Dry etching experiments have been performed on a parallel-plate plasma etcher operating in plasma mode (where the wafer is on the grounded electrode) and analyzed using a spectrophotometer and a scanning electron microscope (SEM). To date, we have found silicon oxide and polysilicon etch rates and polysilicon to oxide selectivities comparable to those of the standard process of 50% $C_2C_lF_5$ using 25%-55% of the alternative gases. Etch profiles in polysilicon for both gases are also similar to those obtained by the standard process. Our findings hold promise for developing a near-anisotropic etching process with one or both of these gases.

Control of AFM Anodization for Lithography of Single-Electron Devices

Andrew MacBeth, SNF

James S. Harris, Dept of Electrical Engr, Stanford University

A fully operational single-electron transistor (SET) was recently demonstrated at room temperature, though the failure of the device occurred quickly. In order for devices of this type to become feasible for use in integrated circuits, their operational lifetime must be improved considerably. Using a negatively biased atomic force microscope (AFM) tip, thin lines of oxide, on the order of several tens of nanometers in width, can be “written” on thin films of metal. When these lines are written between two areas of conductor, a very small metal island can be formed which electrons can tunnel, creating a transistor. In order to improve the lifetime of these devices, the AFM oxidation process must be studied in detail, so that more robust oxides can be produced. We are currently working on determining the optimal voltages and writing speeds for AFM lithography of titanium, aluminum, copper, and niobium. Once these parameters have been well established, we will attempt to fabricate SETs using the various metals and attempt to measure their electrical properties.

Designing an Internal Dialysis Unit

Tavia Marshall, HU

Kimberly L. Jones, MSRCE, Howard University

The objective of this research was to design an efficient, yet biocompatible dialysis unit for internal use. The design of the model was to incorporate the functions and components of traditional dialyzers into a miniaturized unit, with a focus on membrane fabrication. Initially, it was intended to fabricate the membrane material in the Howard University Materials Science Research Center of Excellence. However, our research revealed that the optimum material and membrane could not be fabricated in the MSRCE laboratory. Therefore a theoretical model of an internal unit was designed; however, the actual performance of this unit requires physical experimentation. The model of the unit is similar to a square, three-dimensional box with a housed polysulfone membrane sandwiched in between. The effective separation of substances that pass through the membrane is based on the concepts of diffusion by means of countercurrent flow. Micropumps housed in the unit will be used to regulate blood and dialysate flow. Four portals: blood in, blood out, dialysate in, and waste out, provide for the fluid flow throughout the unit. The unit will be attached to the femur, from which blood will enter and exit via the femoral artery and vein. The waste outlet leads to the bladder, where waste is excreted. Dialysate is pumped into the unit using a “strapped beeper unit,” a unit derived from the insulin pump concept.

Surface Organization by Non-Lithographic Techniques

Rafael N. McDonald, UCSB

David I. Margolese, Galen Stucky, Dept. of Chemistry, UCSB.
Angela M. Belcher, Dept. of Chemistry, QUEST, UCSB.
Evelyn L. Hu, Electrical and Computer Engr, QUEST, UCSB

This project proposes using off-cut semiconductor materials (InP, GaAs, Si) in order to define nanoscale geometries in two-dimensions. The step edges on the off-cut surfaces will be used as anchoring points for silylating agents. These bound agents will provide attachments points for proteins and nanoparticles which will subsequently be interconnected with conducting polymers leading to an ordered surface. The use of proteins to induce circuitry would lead to possibilities in self-fabrication.

Initially nanoparticles of iron (II and III) oxide particles were made. These nanoparticles will be subjected to a library of genetically engineered phage bacteria and the samples that bind best will be identified.

Surface organizations of the natural oxide layers of the semiconductors were studied using the Digital Instruments D3000 Atomic Force Microscope. The hydroxides were stripped off and replaced with 3-mercaptopropyltrimethoxysilane. 1.4 Angstrom diameter gold was then attached to this thiol. The D3000 and SEM were employed again to see if the replacements were successful.

Attempts to see the singular step edges before silylation with the D3000 proved to be beyond its capabilities. Once the gold was attached, the D3000 showed clear conglomerates of gold particles completely covering the surfaces. Attempts to make gamma-Fe_2O_3 have thus far proven unsuccessful. Fe_3O_4 particles on the order of 45 Angstroms and larger in diameter were successfully made.

Characterization of Polyethylene Wear Particles from Artificial Implants Using Atomic Force Microscopy

Catherine McPherson, HU

Mohsen Mosleh, Howard University

Previous study of the wear particles from artificial hip and knee implants has been performed to gain an understanding to the mechanisms which lead to failure. Atomic Force Microscopy has been used in this analysis. In order to gain a better simulation and understanding of implant wear which ultimately caused failure, it is necessary to gain not only topographic information on the wear particles, but information on the mechanical properties as well, such as hardness, adhesion, and viscosity. Previous A.F.M. use has been limited to topographic data only. Different A.F.M. techniques have been researched, examined and used in order to overcome this limitation. While the initial problem has been solved, research has uncovered previously unknown limitations which have yet to be resolved.

Patterned Planar Electrode Arrays for Measuring Neuronal Circuits

Marc Meyer, CNF

Michael Isaacson, Applied and Engineering Physics, Cornell University

Separately both chemical and topographic patterning have been shown to guide the projections of hippocampal neurons in vitro. One method of chemically patterning surfaces is to stamp polylysine on fused quartz or silicon using microcontact printing. Trenches in silicon dioxide and polyimide have also been shown to topographically guide neuronal projections. These patterning techniques can be used to direct the growth of neurons and formation of synapses on a planar electrode array to make a neuronal circuit, in which neurons are made to grow on top of the electrodes in some desired formation. Using this electrode array, individual neurons can be selectively excited with a current pulse and the response of the rest of the neuronal circuit can then be recorded. In the future, this technique may be used to study the mechanisms of neural computation and eventually to gain a better understanding of how the human brain works.

Designing an Internal Dialysis Unit
LaRon Phillips, HU

Kimberly L. Jones, MSRCE, Howard University

The objective of this research was to design an efficient, yet biocompatible dialysis unit for internal use. The design of the model was to incorporate the functions and components of traditional dialyzers into a miniaturized unit, with a focus on membrane fabrication. Initially, it was intended to fabricate the membrane material in the Howard University Materials Science Research Center of Excellence. However, our research revealed that the optimum material and membrane could not be fabricated in the MSRCE laboratory. Therefore a theoretical model of an internal unit was designed; however, the actual performance of this unit requires physical experimentation. The model of the unit is similar to a square, three-dimensional box with a housed polysulfone membrane sandwiched in between. The effective separation of substances that pass through the membrane is based on the concepts of diffusion by means of countercurrent flow. Micropumps housed in the unit will be used to regulate blood and dialysate flow. Four portals: blood in, blood out, dialysate in, and waste out, provide for the fluid flow throughout the unit. The unit will be attached to the femur, from which blood will enter and exit via the femoral artery and vein. The waste outlet leads to the bladder, where waste is excreted. Dialysate is pumped into the unit using a “strapped beeper unit,” a unit derived from the insulin pump concept.

Laser Enhanced Debonding of Nitride Semiconductor Films
Lezlie Potter, UCSB

David Clarke, Materials Dept, UCSB

Gallium Nitride (GaN) devices have garnered a lot of attention recently because of their use in wide band gap semiconductor applications such as blue LEDs and blue lasers. Many limitations exist in growing device material, however, because of the lack of a matched substrate. Currently, films are grown on Sapphire substrates which have both a lattice constant and thermal conductivity coefficient mismatch, causing stresses and high dislocation densities in the GaN devices as they grow and cool.

Thick (100-500μm) films grown by HVPE (Hydride Vapor Phase Epitaxy) can be removed from the Sapphire, though, and could be used as matched substrates for subsequent growth of thin (0.2-2μm) film devices with a lower defect density than those currently produced. Removal is achieved by decomposing the GaN to Ga and N_2 at the substrate interface with pulsed laser energy, separating the film from the Sapphire and allowing the substrate to be lifted off. This debonding process relaxes some of the stress present in the bonded film, as reflected in the Raman spectra of the film before and after its removal. Comparison of the two sets of data reveals that the free standing films have fewer stress-induced lattice vibrations and that the Raman wavelength shift can be calibrated to the film stress.

High-Resolution Dry Etching of Si-Based Dielectrics Using a Chemically Amplified Electron Beam Resist

Jeremy A. Rowlette, PSU

Robert J. Davis, Applied Research Laboratory, Penn State University

As feature sizes in modern ICs shrink into the submicron (nanometer) range, reactive ion etching processes are complicated by phenomenon such as molecular transport, ion angular distribution effects, and image potential effects, among others. This project explores the etching of deep submicron trenches in spin-on-glass and silicon nitride using the combination of direct write electron beam lithography and a magnetically enhanced reactive ion etcher (ME-RIE)

Spin-on-glass films (as much as three layers of Filmtronics 300F) were deposited on Si to form SOG layers, while nitride layers were deposited using plasma-enhanced chemical vapor deposition (PE-CVD). Submicron trench patterns were formed by writing Shipley XP-8934B at 50 KeV at approximately 15 $\mu C/cm^2$ dose using a ~25 nm beam. The XP resist is a negative-tone, novolak-based resist of ~100 nm thickness; chemically amplified, it requires a precise (106°C), 60 sec postbake following exposure. Patterns were transferred into the underlying layer using ME-RIE (Applied Materials P5000) with typically 70 sccm CHF_3, 70 sccm Ar gas flow for 120 sec. Cross-sections of the etched trenches were characterized using scanning electron microscopy.

Etching in SiO_2 in High Aspect Ratio Trenches

Mahima N. Santhanam, PSU

Robert T. McGrath, Engineering, Penn State University

Reactive ion etching (RIE) was used to etch high aspect ratio trenches on silicon dioxide substrates. Reactive ion etch tools provide highly directional (anisotropic) ion fluxes for definition of high-aspect-ratio features used in integrated circuit manufacturing. RIE has many other advantages over conventional wet etching including reproducibility, particle control, and chemical waste minimization. In magnetically enhanced reactive ion etching (ME-RIE) a magnetic field is employed to improve the confinement and directional flow of electrons and ions. The resulting increase in plasma density and in flow anisotropy leads to enhanced etch rates and improved wafer throughput.

In my studies, I used a computer-aided design (CAD) program to define various patterns for photolithography and direct-write electron beam lithography masks. Patterns defined contained trenches 2 mm in length so as to allow for easy subsequent analysis of the trenches that were etched. With photo lithography, trench widths were varied from 2000 nm to 250 nm. After transferring the initial pattern to a photoresist (Shipley 1813 resist) covered SiO_2 wafer, the wafer was etched in an Applied Materials ME-RIE tool operating with a CHF_3 gas discharge. Subsequent to the etch step, samples were placed in a scanning profilometer for measurement of SiO_2 etch rate and etch rate selectivity to resist. Etch times were varied between 30 and 120 seconds, and the SiO_2 etch rate was measured to be ~1000 ≈/min. Some etched wafer samples were cross-sectioned and coated in gold for subsequent measurements of etch profiles in the scanning electron microscope (SEM).

SMITH is Missing: The Enabling of Germanium Processing and Measurement of RF Magnetron Sputtered Film Uniformity for Dark Matter Detectors

Chancy Schulte, SNF

Blas Cabrera, Dept of Physics, Stanford University

Silicon and germanium detectors are used in dark matter detection in the multi-institutional CDMS (Cryogenic Dark Matter Search) experiment. This new class of elementary particle detectors, operating now in the Stanford Underground Facility (SUF) on the Stanford University campus, is based on the simultaneous detection of phonons and of ionization in the silicon or germanium crystals at temperatures below 100 mK. The sensors are photolithographically patterned 40 nm thick tungsten and 300 nm aluminum thin-films deposited on 3 inch diameter silicon or germanium substrates ranging in thickness from 300 µm to 10 mm. For the phonon sensing, the detectors use large area aluminum collector pads, called QET (Quasiparticle-trap-assisted Electrothermal-feedback Transition-edge-sensor).

In this research, work has been done on monitoring the interactions of the germanium substrate with processing chemicals. The germanium chemistry has proven a processing challenge in the past, and in this work, it has been shown that a thin silicon layer, approximately 10 nm, acts as an effective buffer layer in allowing processing on a germanium substrate without chemical complications.

Film characteristics must be monitored and controlled to ensure proper operation of detectors. Tungsten films must have a Tc in the range of 50 to 120 mK for the sensors to behave predictably. Tc, and resistance, may be a function of film thickness. In this research, film thickness is measured in conjunction with systematic assessments of Tc of RF magnetron sputtered tungsten films on silicon substrates. Wafers were photolithographically processed using a mask designed for Tc monitoring. Tungsten film thickness is being measured using equipment including the Dektak Profilometer. Following the overall film uniformity assessment, film sputtering methods will be evaluated for future use in the production of dark matter detectors.

Near-Field Scanning Optical Microscopy and Fiber Optic Tips

Gavin Scott, UCSB

Darron Young, Quantum Institute, UCSB
David Awschalom, Quantum Institute, UCSB

The near-field scanning optical microscope (NSOM) possesses magnification capabilities many times greater than that of the most powerful conventional light microscope, plus it has the ability to produce topographical images thereby doubling as an atomic force microscope (AFM). The near-field microscope utilizes a fiber optic tip to either collect light from the surface of a sample or emit light directly on to the surface. We currently have two separate methods to create these tips. In the first method we use a micro pipette puller to mechanically draw the single mode optical fiber apart creating a sharp tip at the point where the fiber breaks. The second method involves placing the fibers in a buffered hydrofluoric acid solution with a layer of an organic solvent as a protective covering. The second method has produced fiber tips with shorter taper lengths and smaller apertures relative to what was produced with the pulling method. Tests indicate that the tips produced by the etching method are more efficient transmitters of light. Higher efficiency of fiber optic tips will lead to a near-field microscope with improved spatial resolution.

Fabrication of High Aspect-Ratio Nanometer-Scale Structures Using Electron Beam Lithography and Reactive Ion Etching

Keith Slinker, CNF

Dustin W. Carr, CNF, Cornell University

We have developed and characterized etching processes that overcome the difficulties of etching anisotropic high aspect ratio structures at the size scale associated with high-resolution e-beam lithography. Both metal and organic resists were explored as etch masks.

To make a metal etch mask, we patterned ~50 nm features in PMMA on silicon using electron beam lithography. 20 nm of Cr is then deposited and liftoff is performed using organic solvents to remove the pmma. This Cr is then used as an etch mask in a reactive ion etch (RIE).

Sidewall etching is the limiting factor in the case of a CF_4 RIE of silicon, so we added a relatively small amount of H_2 to act as a sidewall passivating agent. This resulted in an anisotropic etch with selectivity to a chrome mask of at least 12:1, an aspect ratio of at least 9:1, and an etch rate greater than 20 nm/min. We added SF_6 to a CL_2/BC_{l3} electron cyclotron resonance (ECR) plasma etch to compensate for the sidewall deposition that occurs in this case. This etch has a selectivity to chrome of at least 15:1 and an etch rate on the order of 300 nm/min. The results reported here are for wall structures in silicon; furthermore, future plans are to characterize both of these etches for pillars, holes, and trenches.

We also used NEB_{22} as an e-beam resist. This required developing a suitable process for this resist, which is quite new and has not been researched thoroughly before this time. The high sensitivity of this chemically amplified resist reduced the exposure time to 2% that of PMMA. Additionally NEB_{22}/PGMEA is a negative tone resist, eliminating the evaporation and lift off steps required with PMMA. Future plans are to characterize the selectivity of NEB_{22}/PGMEA to silicon for various etches.

The Effects of Adding Emulsions to a Polyacrylamide Gel

Linda Steinberger, UCSB

Mike Wyrsta, UCSB
Vinny Manoharan, UCSB
David Pine, UCSB

Polyacrylamide gels are most commonly utilized in gel electrophoresis, a biochemical method utilized for the separation and characterization of proteins, nucleic acids and other subcellular particles. Polyacrylamide is limited in that it is not able to separate segments greater than 10,000bp in length. Polyacrylamide gels are formed by the co-polymerization of acrylamide and bis-acrylamide. The bis-acrylamide randomly crosslinks the polymer chains resulting in closed loops and a complex matrix with a characteristic porosity dependant on the monomer concentrations and polymerization concentrations. The pore size is a factor in determining how large a strand will be able to migrate through the gel.

By adjusting these factors it is possible to achieve pores sizes ranging between 500 - 600 nm. Adding emulsion droplets to the aqueos phase of polyacrylamide allows the gel to polymerize around these droplets. The droplets can subsequently be removed, creating even larger pores. I have been looking at the effects of adding and removing 1 micron emulsion droplets from a polyacrylamide gel in order to see if this is a viable method for forming larger pores which would allow for the separation of larger fragments cellular particles.

Characterization of Thin Films Deposited Using Highly Collimated Molecular Beams of Variable Kinetic Energy

Ben Sturm, CNF

James R Engstrom , Chemical Engr, Cornell University
S.E. Roadman, Chemical Engr, Cornell University

Polycrystalline silicon thin films have been characterized using profilometry and scanning electron microscopy (SEM). The films were deposited on thermally oxidized silicon substrates by means of supersonic molecular beams of tunable kinetic energy. Both a differentially pumped collimated supersonic molecular beam and a supersonic "free jet" were used as sources. To probe deposition kinetics, two studies were initiated. Under conditions of steady state film growth, average thin film growth rates were measured by ex-situ thickness measurements. Standard photolithography techniques were employed to generate a sharp film interface and thus enabled use of a stylus profilometer. Here, the free jet source was used and conditions were such that the limiting factor effecting growth rate is molecular beam flux. It was found that the film thickness data corresponded well with recent simulation results. In the non-steady state case, the nucleation process was examined using the collimated source. Nuclei densities were measured during various stages using SEM. Parameters investigated include substrate temperature and incident beam kinetic energy. Nuclei size varied from 8 to 35 nm prior to coalescence. It was found the nucleation kinetics exhibited a strong dependence with incident beam kinetic energy. An incubation time was measured as a function of substrate temperature and followed an Arrhenius functional dependence with an apparent activation energy of 0.78 eV. This analysis is part of a larger study aimed at understanding and optimizing selective silicon film deposition where effects of both chlorine and atomic hydrogen will be investigated.

Resist Charging and Heating in Electron Beam Lithography

Corina-Elena Tanasa, SNF

Mark McCord, Stanford University

Resist charging on masks during electron beam writing degrades overlay performance in lithography by introducing placement errors. As the feature sizes become smaller and smaller, to the order of nanometers, the errors become more and more significant. To minimize resist charging and resist charging effects an understanding of the resist charging process is needed. Using the MEOC equipment Modular Electron Optical Column we measured the charging of the PBS resist at 10 KV and 20 KV electron-beam voltage, for resist thicknesses from 0.2 to 1.5 micrometers. A very interesting feature of the data is the positive charging of the resist at small thicknesses. It is known that second emission can cause this, but the mechanism is not clear. For thicker resist layers the charging becomes negative. In passing from positive to negative charging thicknesses, there is a thickness where the charging of the resist is zero. We use these experimental data to develop a model of the resist charging process.

The other part of the project involves testing of two new resists, UV_5 and UVN_2. These resists can replace many resists that are used now in nanometer-scale patterning. We are searching for the parameters /temperature, time constants, dose - that lead to the clearest features on the wafer exposed in the Hitachi HL-700F Electron Beam Lithography Machine with the test pattern we designed. Upon my return to Stanford we will make SEM images of the profile of the best patterned wafers.

Mechanical and Microstructural Properties of Lightweight Ceramic Ablators

Patricia Valenzuela, UCSB

Kelly Parmenter, UCSB
Fred Milstein, UCSB

High temperature and high strength heat shields are needed for proposed manned exploration of other interstellar planets. On these missions, the space vehicle will experience severe heat loads during the descent into a planet's orbit. Lightweight Ceramic Ablators (LCA's) were recently developed at NASA Ames Research Center for the purpose of using a low-density fibrous substrate as an ablative heat shield. These ablative materials will need to protect the vehicle from both a high radiative environment and a high shear load. In order to optimize the development and use of LCA's, it is necessary to measure the properties and behaviors of these materials, including the thermophysical, thermochemical, mechanical, and microstructural characteristics. We are performing several mechanical tests to thoroughly understand the behavior of these materials in a highly stressful environment. Arc-jet tests have been conducted to analyze the thermal performance and ablation characteristics of the LCA's in a high enthalpy, hypersonic flow environment.

The tests we performed have been hardness, compression, and shear. The three types of material that make up the LCA family are Phenolic Impregnated Carbon Ablator (PICA), Silicone Reusable Carbon Ablator -Fibrous Refractory Composite Insulation (SIRCA-FRCI), and Silicone Reusable Carbon Ablator-Ames Insulation Material (SIRCA-AIM). We ran our tests using the Instron 1123 because it is extremely useful for several kinds of mechanical testing. There is a minimum of ten tests that are run for each type of material. Results indicate that the strength will vary in materials and in the direction the fibers are placed.

Annealing Behavior of Ar^+ Plasma-Damaged InAs Quantum Dots and InGaAs Quantum Wells

Ben Werner, UCSB

Pierre Petroff, UCSB

Quantum wells (QWs) and quantum dots (QDs) are semiconductor structures grown using molecular beam epitaxy (MBE) which allows deposition of atomic monolayers. QDs and QWs are grown small enough such that quantum behavoir such as confinement of single electron-hole pairs in QDs and a "tunable" emmission/absorsion wavelengh or bandgap in QDs and QWs is exhibited. The issue of radiation resistance is relevant to the performance of many semiconductors since plasma radiation is used in device fabrication. A previous study by Winston Schoenfeld has shown that QDs are more resistant to Ar^+ radiation than QWs, however we can't account for the presence of radiation induced damage at the depths of the active regions in the QD and QW samples. We are prompted to examine more closely the dynamics of radiation-induced point defect migration in these devices. In our experiments we anneal Ar^+ plasma-damaged QD and QD samples using the rapid thermal annealing (RTA) technique which facilitates point defect migration. We then measure the photoluminescence (PL) of the samples which gives us the wavelengths and intensities at which the sample is absorbing and emitting light. Comparing the PL of the damaged and annealed samples to control samples tells us whether or not the point defects are propagating into the active regions. Considering the structure of the our QD and QW samples we can make an inference as to mechanism for point defect migration in these and similar devices.

Film Thickness' and Surface Topology Measurements Support the Successful Growing of Ferroelectric $SrBi_2Ta_2O_9$ Thin Films

Isaiah W. Williams, PSU

Darrell G. Schlom, Materials Science & Engr, PSU

Currently, the natural procession for epitaxial $SrBi_2Ta_2O_9$ thin films, aspires and attempts to grow and measure (001) and (110) orientations by pulsed laser deposition on (001) $LaAlO_3$-Sr_2AlTaO_6 and (100) $LaSrAlO_4$ substrates respectively. The epitaxial growth of (001) $SrBi_2Ta_2O_9$ on (001) $LaAlO_3$-Sr_2AlTaO_6 (LSAT) and (110) $SrBi_2Ta_2O_9$ on (100) $LaSrAlO_4$ is feasible by pulsed laser deposition (PLD). For the successful growth of (001) and (110) it is crucial to minimize the surface mesh mismatch between the film and substrate, thus permitting epitaxial growth. In order to validate our hypothesis that minimizing surface mesh mismatch indeed permits epitaxial growths by measurements.

I used both scanning electron microscopy (SEM) and profilometry to obtain topographical data and deposited thickness' of (001) and (110) orientation. Collectively, the data shows that there are considerable amounts of surface contaminants on the film. The film thickness' measured are used to calculate the electric field of the film, so that the ferroelectric properties may be derived. In conclusion, measuring surface topology and film thickness with the SEM and profilometer, assist us in measuring the anisotropic ferroelectric properties of $SrBi_2Ta_2O_9$ films. While at the same time, these measurements also suggest that (001) and (110) orientations are being grown within acceptable parameters.

II-VI Semiconductor Nanocrystals Synthesized in Solution Phase

Katie Wooton, UCSB

Geoff F. Strouse, Chemistry, UCSB

A nanocrystal refers to an amount of any crystalline material small enough to show significant quantum effects, usually between 1 and 100 nanometers. The physical and optical properties of many semiconducting materials are known to vary with size in the nanocrystal range. The goals of this project were to control synthesis of ZnS and CdS clusters, to substitute organic molecules for capping groups on these clusters, and to assemble the clusters into a working circuit. Several discrete sizes of ZnS and CdS clusters were synthesized in solution. These clusters were identified by electron spray mass spectrometry (ESMS). Absorption spectra were gathered in order to determine the relationship between cluster size and wavelength of light absorbed. On the smallest clusters, halides (I and Br) were substituted for the capping groups. No method has yet been determined for replacing halides with organic groups.